

one region and lowered in another during the same year. This is necessary in order to avoid the difficulty of making the total weight of the earth's atmosphere vary from year to year. When the pressure is generally high in North or South America, it is low in Asia, the Indian Ocean, and Australia. This condition is brought about by some profound modification in the circulation of the earth's atmosphere, by which high areas tend to form in one hemisphere at the same time that low areas prevail in the opposite hemisphere. In a similar way the changes of temperature from year to year are such that in the tropical zones, where the sun shines fully on the earth's surface, temperatures rise and fall directly with the solar prominence frequency; but in the middle latitudes of the earth the opposite or reverse conditions of temperature prevail. Hence, when solar activity increases and more spots or prominences can be seen, there is an increase of heat in the earth's Tropics, and this produces an increase in the circulation of the entire atmosphere. The warm air of the Tropics rises more rapidly than usual, the cold air of the upper strata over the temperate zones pours down vigorously upon the United States, Europe, and Asia, and these countries are covered with a rapid succession of pronounced cold waves, such as have marked the years 1904 and 1905.

The increase in solar activity shows itself in yet another way. By putting together the tables of prominences so as to study their behavior in longitude, that is around the sun in the same zones, it has been found that the retardation of the solar rotation in the higher latitudes relative to the primary equatorial period of 26.68 days, sways backward and forward in harmony with the same prominence frequency curve. This indicates that the internal solar energy, in trying to free itself after accumulation and congestion, sends forth great waves, which rotate the circulation in the polar zones farther backward. The visible symptoms of this operation at the surface are changes in the number and location of the prominences, the faculae, the sun spots, the granulation of the photosphere, and in the form and extent of the great coronal streamers. Besides this visible effect of the internal action, there is the more important and invisible radiation which streams from the sun and falls upon the earth.

Besides the general synchronism in the solar action just outlined, we have a corresponding movement in the earth's atmosphere embracing the magnetic and electrical forces, the pressure, temperature, vapor tension, and precipitation. Conflicting evidence will no doubt be reconciled by a more thorough study of the underlying facts of inversion, and generally the entire subject needs most careful investigation.

#### THE METEOROLOGICAL WORK OF THE U. S. NAVAL ECLIPSE EXPEDITION TO SPAIN AND ALGERIA, AUGUST 30, 1905.

By Prof. FRANK H. BIGELOW. Dated Daroca, Spain, August 27, 1905.

At the request of Rear-Admiral C. M. Chester, U. S. N., Commander in Chief of the Special Service Squadron *Minneapolis*, *Dixie*, and *Cesar*, sent to observe the total eclipse of the sun, August 30, 1905, in Spain and north Africa, the Chief of the Weather Bureau detailed myself and Dr. Stanislav Hanzlik to carry out the meteorological observations required in this connection. Advantage was taken of the voyage on the *Cesar*, which sailed from Norfolk on June 22, to make some kite ascensions with self-recording meteorographs for data over the ocean, and, also, to observe the electrical conditions near the water areas. We secured seven ascensions on the trip to Spain, and have made suitable preparations to continue the work on the return voyage in September. The southwest current prevailing on the western side of the Atlantic reached its maximum force about 1000 miles east of Norfolk, and the northeast current on the eastern side was at a maximum less than 500 miles from Spain. The former is much broader than the latter, and the wind did not reach a

velocity as great on the western side as on the eastern side of the Atlantic. We found that there was no tendency to reversal of the temperature gradients such as Hergesell observed farther to the south in the trades, and we did not note any important diurnal variation of the temperature even at short distances above the surface of the ocean, though the kites were in the air as much as eight hours during several days. The electrical observations on the *Cesar* include a few records of the potential gradient over the side of the ship, an excellent series of observations on the coefficient of dissipation with the Elster and Geitel apparatus, and a complete set for the number of ions per cubic centimeter with the Ebert apparatus, the velocity observations being omitted. All these electrical records were made in the calm region surrounding the Azores, lying between the two great currents just mentioned.

After landing at Gibraltar the expedition separated into two branches, Doctor Hanzlik in charge of the part in Algeria, and Professor Bigelow in charge of that in Spain. The African party sailed for Bona on July 19, and the astronomical and meteorological station was established at Guelma. It was planned to organize two secondary stations to supplement the work at Guelma, but these seem to have been abandoned for some reason. The Spanish parties landed at Valencia July 24, and the work of equipping the several stations proceeded regularly to a conclusion. On July 25 a meteorological station was arranged in the Institute of Castellon, Señor José Sanz Bremon, Director; on July 27 another station was planned at Tortosa, or rather the Director of the Cosmical Observatory of the Ebro, Rev. P. R. Cirera, S. J., agreed to furnish copies of the regular records as desired. The plan of this observatory is similar to that of the Mount Weather Research Observatory and contains a very excellent equipment of modern instruments and a corps of competent observers. As it is located within the belt of the eclipse shadow, it ought to give a fine account of itself, having such remarkable advantages for this occasion. On July 30–August 1 the work was organized at Porta Coeli, where the astronomical station No. 2, near the southern border of the track, was located. Besides the regular meteorological instruments, an Elster and Geitel apparatus and a potential electrometer were put in operation, and Messrs. Scrivener and Straupe being left in charge. This station has been in operation for fully four weeks, a portion of the time day and night, and a very extensive series of observations is in hand.

On August 3–6 another station was installed at Daroca in connection with the astronomical station No. 1, near the center of the belt. In addition to the instruments mentioned at Porta Coeli, an Ebert apparatus for the number and velocity of the ions, a Brashear polarimeter, and a solar image telescope were set up. It was intended to execute a series of radiation observations with a mercury actinometer, but the copper box as originally made failed and it was not possible to secure a new one till too late to make that work profitable. The magnetic observations were inadequately organized at this station and will not be important in this connection. All the instruments at Daroca have been in constant use by myself aided by Messrs. Rickerd, Trainor, and Olivier, and we have obtained several thousand observations, some of the electrical series continuing uninterruptedly day and night for more than a week. From Daroca I proceeded to Zaragoza and arranged for suitable observations at the Colegio del Salvador in charge of Rev. José Albiñana, S. J., August 8; then to Guadalajara, where similar observations will be furnished by Lieut. Col. Pedro Vives y Vich, chief of the Spanish aerostatic service, who, also, has charge of all the balloon ascensions at Burgos undertaken by the International Committee during this eclipse. The homing pigeon service and the balloon equipment at Guadalajara were very interesting and instructive.

A brief visit to Madrid for supplies, and to see the Astronomical Observatory, followed, and finally I returned to Daroca August 13. Observations will be continued regularly till the day following the eclipse, August 31, when the various pieces of apparatus will be gradually collected from the several places and put aboard the *Cesar*, which will sail from Nice on September 13 for the United States.

The climate in Spain has proved to be unexpectedly agreeable and favorable for such an eclipse expedition as this. The air is generally dry and for the most part cloudless; there have been no thunderstorms and no rains for weeks; the temperature at Daroca, 2200 feet above the sea, reaches about 90° F. at midday, but falls to 50° or 60° every night. The extreme heat was 95° on two days, and the lowest night temperature 42°. It should be noted that in the daytime the relative humidity falls to about 40 per cent on the average, but on the hottest days to 25 or 30 per cent, while at night it rises to above 90 per cent, often to 96 per cent. This wide range of temperature and relative humidity is accompanied by a remarkably steady barometer, ranging about two-tenths of an inch per day, and only four-tenths of an inch during several weeks. The cyclonic system that prevails in the United States does not seem to exist in Spain in the summer. On the sea coast the sea breeze is especially vigorous, so that the stations Porta Coeli, Castellon, and Tortosa will record that feature fully in connection with the eclipse, while the inland stations Daroca, Zaragoza, and Guadalajara, will be free from it. This will enable us to study the so-called "eclipse cyclone" with data bearing directly upon the subject. The circulars containing instructions regarding the shadow bands have been distributed very widely and there is an apparent interest in this subject.

The Spanish people have been most hospitable toward the American eclipse parties, and indeed to all the visiting scientists, of whom there are now many in Spain, and they have always most cordially assisted in carrying out the plans proposed for the benefit of the expeditions. We shall always recall their hospitality with feelings of gratitude and obligation.

#### DAROCA, SPAIN, August 30, 1905.

The total eclipse was an entire success at this station so far as the weather was concerned. The 29th had been a very anxious day, because it was heavily clouded, with occasional showers, for the first time in four weeks, but the wind shifted from west to north toward evening, the temperature dropped to 40° during the night and the morning of the 30th was fair. There were numerous cumulus and alto-cumulus clouds, but they gradually dissipated by noon, and at 1 p. m. the region around the sun was exceptionally clear. The sky polarization was 58 per cent during the eclipse, and while we have had occasional readings of 72 per cent, this means an atmosphere quite clear of uncondensed vapor. The barometer remained unaffected, the temperature dropped 8° F. in the shade and 18° in the sunshine. The wind was very light and there seemed to be no special change during the middle hour of the eclipse. The shadow bands were very feeble and disappointing, but they were seen for 40 seconds ending within 15 seconds of the second contact, and again less distinctly for a half a minute from about 30 seconds after the third contact. Their direction of motion was along the central line and they lay exactly perpendicular to it; their width was such as to give about two bands and three spaces to the foot; the velocity was about three feet per second. The electrical observations were carried on without interruption from 6 a. m. till 8 p. m., but the results can not be stated without computation. The corona as seen through the opera glass and in my 3.5-inch telescope was a beautiful sight, as usual, typical of the corona at the maximum of the sun-spot period. Two common sized spots and

three smaller ones were present, and the times of contacts I and IV and the passage of the limb of the moon over these spots were noted at least approximately. The rays of the corona were generally radial, the polar curved rays being obscure and irregular. There were several stellar points on the streamers, which extended generally two diameters from the sun. There were no very extensive streamers, but the corona was bright and rather condensed, of a steel gray, pearly color, as seen in some electrical phenomena; the inner corona was brilliant and there were two long groups of superb rosy-tinted prominences which will become famous in the history of solar eclipses. The work with the spectroscopes and cameras at Daroca is believed to have been of the best quality, but it is not known at this time what special information was secured. The health of the entire party of twenty persons has been excellent.

#### OBSERVATIONS OF EARTH TEMPERATURE IN JAPAN.

By DR. S. TETSU TAMURA. Dated Washington, D. C., June 10, 1905.

##### (1) INTRODUCTION.

The earth's crust and the outer soil furnish examples of the periodic flow of heat that illustrate Fourier's beautiful theorem. If the earth's surface be heated and cooled periodically, a thermometer sunk in the ground will exhibit corresponding variations of temperature. By day the surface of the earth is heated, a diurnal temperature wave is propagated into the interior and the indication of the thermometer gradually rises. As the earth's surface is cooled at night, the thermometer will exhibit a fall of temperature. If, therefore, the surface temperature is a periodic function of the time, then the temperature at any depth will vary in a corresponding periodic manner. When the periodic variation has been maintained for a sufficient time, the oscillations of temperature, at any depth, will attain a fixed character so that the mean temperature at each point remains steady. There are also annual temperature waves due to heating during summer and cooling during winter, and irregular oscillations, due to cloudiness, rainfall, snow on ground, etc.

If  $\theta$  is the temperature of the soil at any depth  $x$ ,  $t$  the time, and  $a^2$  the diffusivity<sup>2</sup> of the soil, we have the equation:

$$\frac{\partial \theta}{\partial t} = a^2 \frac{\partial^2 \theta}{\partial x^2}. \quad (1)$$

If  $\theta$  is a periodic function of the time  $t$ , or  $\theta = F(t)$  for the earth's surface  $x = 0$ , we can integrate the above equation readily. As the equation (1) is linear with a constant coefficient we get a particular solution by the following device used in articles 7 and 8 of Byerly's, Fourier's Series and Spherical Harmonics. Let

$$\theta = e^{\beta t + \alpha x}$$

and substitute this in (1): we obtain  $\beta = \alpha^2 a^2$

whence

$$\theta = e^{\beta t \pm \frac{x}{a} \sqrt{\beta}} \quad (2)$$

which is a solution of equation (1) no matter what value is given to  $\beta$ .

In order to put this into a more convenient trigonometric form, replace  $\beta$  by  $\pm \beta i$  and equation (2) becomes

<sup>1</sup> More than a year ago Doctor Tamura consented to give us some account of work done by Japanese meteorologists, which promise, however, could not be fulfilled until to-day, on account of the pressure of his other work. The paper here given is a review of memoirs on the earth-temperature observations by his compatriots, Doctors Nakamura, Oishi, and Okada. Doctor Tamura has added, as an explanation, a note on the mathematical principle of the problems of earth temperature that will facilitate the reading by those who are not familiar with the subject.—[E.D.]

<sup>2</sup> The diffusivity of the soil  $a^2 = \frac{k}{\rho c}$  where  $k$  = the conductivity of the soil,  $\rho$  its density, and  $c$  its specific heat. These four quantities are assumed constant in the mathematical analysis, but actually they vary with the water in the soil and also with the distance below the surface.